PRELIMINARY SURVEY REPORT:

PRE-INTERVENTION QUANTITATIVE RISK FACTOR ANALYSIS

FOR SHIP CONSTRUCTION PROCESSES

at

BATH IRON WORKS CORPORATION SHIPYARD,
Bath, Maine

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PLANT SURVEYED:	Bath Iron Works Corporation shipyard, General Dynamics, 700 Washington Street, Bath, Maine 04530
SIC CODE:	3731
SURVEY DATE:	April 17-19, 2000
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ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations at Bath Iron Works shipyard in Bath, Maine as a method to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. This survey was conducted as part of a larger project, funded through Maritech Advanced Shipbuilding Enterprise and the U.S. Navy, to develop projects to enhance the commercial viability of domestic shipyards. Several operations were identified for further analysis including: unloading of small parts for subassembly, connecting electrical cables at a junction box, pulling cable through the vessel, equipment load-in, insulation installation, welding, and grinding. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Possible engineering interventions to address these risk factors for each task are briefly discussed.

I. INTRODUCTION

IA. BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposures to potential chemical and physical hazards, including the study of engineering aspects of health hazard prevention and control.

Since 1976, NIOSH had conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of the completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies had been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

IB. BACKGROUND FOR THIS STUDY

The domestic ship building, ship repair, and ship recycling industries have historically had much higher injury/illness incidence rates than those of general industry, manufacturing, or construction. For 1998, the last year available, the Bureau of Labor Statistics reported that shipbuilding and repair (SIC 3731) had a recordable injury/illness incidence rate of 22.4 per 100 full-time employees (FTE), up from 21.4 in 1997. By contrast, in 1998, the manufacturing sector reported a rate of 9.7 per 100 FTE, construction reported a rate of 8.8 per 100 FTE, and all industries reported a rate of 6.7 injuries/illnesses per 100 FTE. When considering only lost workday cases, for 1998, shipbuilding and repair had an incidence rate of 11.5 per 100 FTE, compared to manufacturing at 4.7, construction at 4.0, and all industries at 3.1 lost workday injuries/illnesses per 100 FTE.

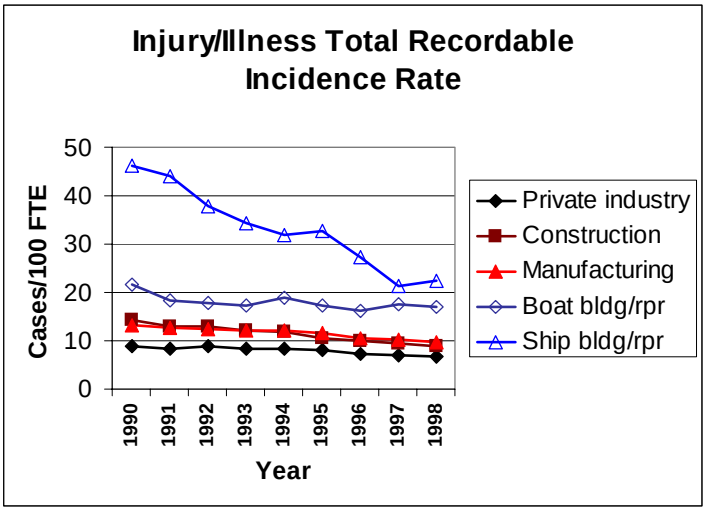


Figure 1. Injury/Illness Total Recordable Incidence Rate

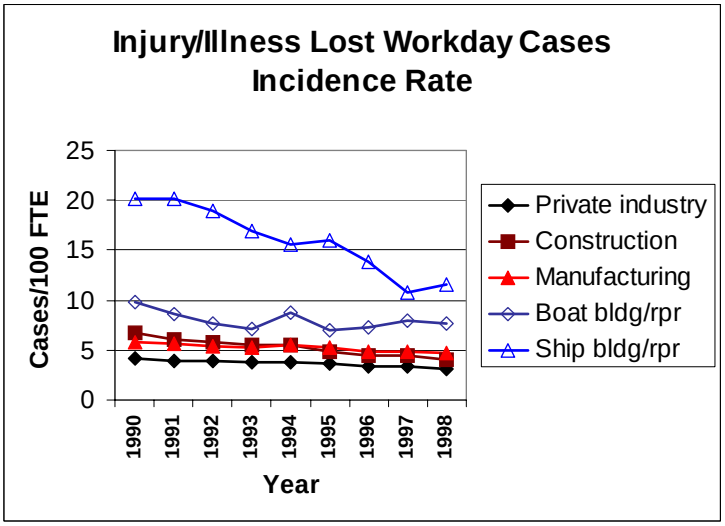


Figure 2. Injury/Illness Lost Workday Cases Incidence Rate

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses to specific parts of the body resulting in days away from work, for the year 1997, shipbuilding is significantly higher in a number of instances. For injuries and illnesses to the trunk including the back and shoulder, shipbuilding reported an incidence rate of 207.7 cases per 10,000 FTE, compared to manufacturing at 82.1 cases. For injuries and illnesses solely to the back, shipbuilding reported 111.1 cases per 10,000 FTE, compared to manufacturing's incidence rate of 52.2 cases. For the lower extremity, shipbuilding reported 145.0 cases per 10,000 FTE compared to manufacturing at 40.8 cases. For upper extremity injuries and illnesses, shipbuilding reported an incidence rate of 92.2 cases per 10,000 FTE while manufacturing reported 73.4 cases.

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses resulting in days away from work, for the year 1997, by nature of injury, shipbuilding is significantly higher in a number of categories. For sprains and strains, shipbuilding reported an incidence rate of 237.9 cases per 10,000 FTE, compared to manufacturing's incidence rate of 91.0 cases. For fractures, shipbuilding reported 41.7 cases per 10,000 FTE, compared to manufacturing at 15.8 cases. For bruises, shipbuilding reported 61.3 cases per 10,000 FTE, compared to manufacturing at 21.5 cases. The median number of days away from work for shipbuilding and repairing is 12 days, compared to manufacturing and private industry's median of 5 days.

Beginning in 1995 the National Shipbuilding Research Program began funding a project looking at the implementation of ergonomic interventions at a domestic shipyard as a way to reduce Workers' Compensation costs and to improve productivity for targeted processes. That project came to the attention of the Maritime Advisory Committee for Occupational Safety and Health (MACOSH), a standing advisory committee to the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) began an internally funded project in 1997 looking at ergonomic interventions in new ship construction facilities. In 1998, the U.S. Navy decided to fund a number of research projects looking to improve the commercial viability of domestic shipyards, including projects developing ergonomic interventions for various shipyard tasks or processes. Project personnel within NIOSH successfully competed in the project selection process. The Institute currently receives external project funding from the U.S. Navy through an organization called Maritech Advanced Shipbuilding Enterprise, a consortium of major domestic shipyards.

Shipyards participating in this project will receive an analysis of their injury/illness data, will have at least one ergonomic intervention implemented at their facility, and will have access to a website documenting ergonomic solutions found throughout the domestic maritime industries. The implementation of ergonomic interventions in other industries has resulted in decreases in Workers' Compensation costs, and increases in productivity.

Researchers will initially identify participating shipyards and analyze individual shipyard recordable injury/illness databases. Then ergonomic interventions will be implemented in each

of the shipyards. Intervention follow-up analysis will be completed approximately six to nine months after intervention implementation. A series of meetings and a workshop to document the ergonomic intervention program will be held at the conclusion of the project.

IC. BACKGROUND FOR THIS SURVEY

Bath Iron Works Corporation was selected as a candidate yard for this study for a number of reasons. In the mid-1990's, a pilot ergonomics intervention project at Bath Iron Works was funded by the National Shipbuilding Research Program. This interest in ergonomics within the shipyard was an indication of the possible cooperativeness in this project. Additionally, it was decided that the project should look at a variety of ship yards based on product, processes and location. Bath Iron Works constructs AEGIS guided missile destroyers for the U.S. Navy and is considered a large shipyard. In fact, Bath Iron Works is the largest private employer in the State of Maine.

II. PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: Bath Iron Works Corporation is located on the Kennebec River in Bath, Maine, approximately thirty miles northeast of Portland, Maine. The main facility of approximately 40 acres includes three inclined shipways able to accommodate ships of 720 feet in length and 112 to 128 feet in breadth or beam. Two principal structural assembly buildings combine for over 208,000 square feet of covered work area providing space for 28 distinct work station locations. The pre-outfit building of about 91,000 square feet provides space for 18 work stations for equipment installation after structural units are blasted and painted. Two cranes, with lifting capacities of 330 and 220 metric tons, service the shipways. Three piers have an overall waterfront length of 2230 feet.

Three other nearby facilities provide additional space for structural fabrication, sub-assembly and final assembly operations, as well as overhaul and repair operations. Currently, Bath Iron Works is in the midst of its most significant facility modernization in its history. A 15-acre expansion into the Kennebec River will include a land-level facility for assembly and erection of ships and a 750-foot floating drydock for the launch and retrieval of ships. It is expected that this new land-level facility will create dramatic process improvements over the current method of construction on inclined building shipways.

Corporate Ties: In 1995, Bath Iron Works was purchased by General Dynamics. The Marine Systems group of General Dynamics includes three ship construction and repair companies (Bath Iron Works, Electric Boat, and NASSCO) and one ship operating company (American Overseas Marine).

Products: Bath Iron Works is the lead designer and builder of the ARLEIGH BURKE class AEGIS guided missile destroyers for the U.S. Navy. These ships are considered to be the most technologically advanced surface combatant ships in the world today. These ships are 505 feet in overall length by 66 feet in beam (width) and displace 8,315 tons under full load. Since the 1950's Bath Iron Works has served as lead shipyard for 10 classes on non-nuclear surface ships for the U.S. Navy, including frigates, cruisers, and destroyers. Bath Iron Works is scheduled to construct an amphibious transport dock ship (LPD) for the U.S. Navy for delivery sometime after 2002. Bath Iron Works has produced over 400 ships since its opening.

Age of Plant: Bath Iron Works' first ship was delivered to the U.S. Navy in 1890. The majority of production facilities have been built in the last 25 years. Facility expansion is underway to provide a land-level assembly area.

Number of Employees, etc: Bath Iron Works employs approximately 7,300 workers. About 4,300 production workers are employed at the main facility. The approximate average age of the production workers is 45 years old.

IIB. PROCESS DESCRIPTION

Steelyard - Steel plate, beams, angle iron and other raw stock material is delivered to the Hardings Fabrication Facility via trucks and placed into the steel yard. Material is unloaded by overhead cranes and placed into storage. Material handlers then load internal railroad cars with material for the surface preparation process.

Surface Preparation - Steel plate and other forms of raw stock are put through a Wheel-O-Brator unit. This unit heats the raw stock to remove moisture, then processes the material through a steel-shot abrasive blast which removes all rust and/or mill residue, and moves the material via large conveyors through a primer paint booth. Once completed, items are loaded either on Bath Iron Works transportation trucks and delivered to the main facility panel line building for unit construction, or delivered to other production areas within the Hardings Facility. Handling of raw stock is performed by overhead gantry, magnetic, diesel, and mobile cranes as well as forklifts. Some manual material handling of raw stock is performed on angle bar, flat bar and many of the other small items.

Panel Line Building – Steel plates are delivered to the east end of the panel line via Bath Iron Works transportation and/or outside vendor trucks. Here the plates are welded together by shipfitters and, by way of a large conveyor, moved up the line where structural members are laid out, and chalk lines are snapped using detailed drawings. Major structural beams are then fitted and welded into place forming bulkheads, decks, and overhead units. Most items are mechanically moved from one area to another via overhead bridge cranes.

Sub-Assembly – Sub-assembly processes are performed at both the Hardings Fabrication Facility and in the Pre-Outfit One (PO1) area located within the Assembly Building at the Bath facility.

In these areas, sub-assemblies are fabricated including; individual foundations, ships doors and hatches, light trays, vent etc. Once completed these items are shipped to the Assembly Building for installation and assembly into large units. Some manual material handling is performed in the sub-assembly areas. Mechanical lift assists are available in some of the areas where heavier lifting is performed.

Assembly – The majority of assembly is performed within the main Assembly Building in Bath. Here units are assembled and outfitted with various structures. Some units are inverted to assist with the installation of decks and inner bottom sections. Some piping and ventilation work is also performed within the Assembly Building. Once initial assembly is completed the units are moved into the Steel Abrasive Blast and Paint building via a large transporter. Once the unit has been blasted and painted it is transferred to the Pre-Outfit Two Building (PO2) where the final assembly/outfitting is performed prior to the unit being transported to the building ways. In the PO2, multiple tasks are performed including: the installation of insulation, pipes valves, lights, and machinery gauge boards; and the initial hook-up of machinery. The longer that units are in the construction process the less control exist over the work environment. Manual material handling and awkward postures are common in these areas.

Ways – Units are attached/erected to form the superstructure. Once units are in place, cable pulling, tank grinding, painting and other general construction tasks are performed. Final painting of the outside hull is completed prior to ship launch. Gantry cranes perform the heavy lifting to get items on-board. Once on the deck, employees carry items to the work areas. Significant material handling and awkward postures are assumed in this area.

Ship Completion – Once ships have been launched completion work is performed. This includes: pipe covering, final painting, decking, machinery space fine tuning, electric hook-up, final outfitting of sleeping quarters, galley, crews mess, etc. Very similar to work on the ways, once the ship is in the water, significant material handling is performed and awkward/confined postures are assumed as the available work space is limited.

IIC. POTENTIAL HAZARDS

Major Hazards: Awkward postures, manual material handling, confined space entry, welding fumes, UV radiation from welding, organic solvent fumes, segmental vibration.

III. METHODOLOGY

A variety of exposure assessment techniques were implemented where deemed appropriate to the job task being analyzed. The techniques used for analysis include: 1) the Rapid Upper Limb Assessment (RULA); 2) the Strain Index; 3) a University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders; 4) the OVAKO Work Analysis System (OWAS); 5) a Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling; 6) the NIOSH Lifting

Equation; 7) the University of Michigan 3D Static Strength Prediction Model; and 8) the PLIBEL method.

The Rapid Upper Limb Assessment (RULA) (McAtamney and Corlett, 1993) is a survey method developed to assess the exposure of workers to risk factors associated with work-related upper limb disorders. On using RULA, the investigator identifies the posture of the upper and lower arm, neck, trunk and legs. Considering muscle use and the force or load involved, the investigator identifies intermediate scores which are cross-tabulated to determine the final RULA score. This final score identifies the level of action recommended to address the job task under consideration.

The Strain Index (Moore and Garg, 1995) provides a semiquantitative job analysis methodology that appears to accurately identify jobs associated with distal upper extremity disorders versus other jobs. The Strain Index is based on ratings of: intensity of exertion, duration of exertion, efforts per minute, hand and wrist posture, speed of work, and duration per day. Each of these ratings is translated into a multiplier. These multipliers are combined to create a single Strain Index score.

The University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986) allows the investigator to survey a job task with regard to the physical stress and the forces involved, the upper limb posture, the suitability of the workstation and tools used, and the repetitiveness of a job task. Negative answers are indicative of conditions that are associated with the development of cumulative trauma disorders.

The OVAKO Work Analysis System (OWAS) (Louhevaara and Suurnäkki, 1992) was developed to assess the quality of postures taken in relation to manual materials handling tasks. Workers are observed repeatedly over the course of the day and postures and forces involved are documented. Work postures and forces involved are cross-tabulated to determine an action category which recommends if, or when, corrective measures should be taken.

The NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996) is an example of a simple checklist that can be used as a screening tool to provide a quick determination as to whether or not a particular job task is comprised of conditions that place the worker at risk of developing low back pain.

The NIOSH Lifting Equation (Waters et al, 1993) provides an empirical method to compute the recommended weight limit for manual lifting tasks. The revised equation provides methods for evaluating asymmetrical lifting tasks and less than optimal hand to object coupling. The equation allows the evaluation of a greater range of work durations and lifting frequencies. The equation also accommodates the analysis of multiple lifting tasks. The Lifting Index, the ratio of load lifted to the recommended weight limit, provides a simple means to compare different lifting tasks.

The University of Michigan 3D Static Strength Prediction Program (University of Michigan, 1997) is a useful job design and evaluation tool for the analysis of slow movements used in heavy materials handling tasks. Such tasks can best be analyzed by describing the activity as a sequence of static postures. The program provides graphical representation of the worker postures and the materials handling task. Program output includes the estimated compression on the L5/S1 vetebral disc and the percentage of population capable of the task with respect to limits at the elbow, shoulder, torso, hip, knee and ankle.

The PLIBEL method (Kemmlert, 1995) is a checklist method that links questions concerning awkward work postures, work movements, design of tools and the workplace to specific body regions. In addition, any stressful environmental or organizational conditions should be noted. In general, the PLIBEL method was designed as a standardized and practical assessment tool for the evaluation of ergonomic conditions in the workplace.

Several specific processes were identified for further analysis. Each of these processes are examined in greater detail below.

IIIA. BIN LOADING BY MATERIAL HANDLERS IN THE PANEL LINE ASSEMBLY AREA

IIIA1. Bin Loading Process

Pre-cut shapes are shipped into the east end of the panel line from off-site facilities in large metal shipping containers. Shipping containers are delivered by forklift and are placed into the material handling area by utilizing a hand operated pallet jack. Overall process is as follows:

1. Material handlers remove individual pieces from the shipping containers and identify hull, unit and job and other pertinent numbers. Quantity, size, and material are compared with shipping documents to assure accuracy.

Figure 3. Bin Unloader Removing Material from Bin

2. Once an item has been identified, it is carried and placed onto the appropriate shelf and location marked on receiving documentation.

Figure 4. Bin Unloader Carrying Material to Shelves

3. Shapes/pieces are then arranged on the shelves to allow easy retrieval by shipfitters working within the area.

4. Once item has been removed from the bin, checked in, and placed on the appropriate shelf, employee returns to the shipping container, and repeats the process until the bin has been emptied. This walking back to the shipping bin could be considered a rest break from material handling.

IIIA2. Ergonomic Risk Factors for Bin Loaders (Material Handlers) in the Panel Line Assembly Area

During the loading/unloading tasks, material handlers assumed significant forward trunk flexion $\geq$ 90 degrees. Shoulder flexion is performed when reaching into the bottom of the shipping containers. This is coupled with a forceful pinch grip that is magnified due to awkward wrist postures (wrist extension). Grip strength requirements are high due to size, weight, type of material handled and the wearing of leather work gloves. Lifting and carrying tasks are regularly performed. Weights of objects vary with dimensional differences. Neck extension is performed when unloading metal shipping bins. Forward neck and trunk flexion is performed when arranging shapes onto racks. While removing material from bins and stacking the material on racks, the bin loader experiences a number of ergonomic risk factors. These risk factors include awkward postures such as extreme lumbar flexion, as well as excessive loads to low back and shoulders.

IIIA3. Ergonomic Analysis of Bin Loaders (Material Handlers) in the Panel Line Assembly Area

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the bin loader. A Rapid Upper Limb Assessment was conducted for the bin loaders (Table 1), analyzing four sub-tasks with unique postures. One of the four subtasks, lifting piece from bin, scored a 7 (investigate and change immediately) on a scale of 1 to 7. Two other subtasks, piece carrying and rack arranging, resulted in scores of at least 3 (investigate further). The final subtask of walking back to the bin was deemed "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the bin loader (Table 2) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be between 9 and 14, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 10.1. An SI score between 5-30 is correlated to an incidence rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the bin unloader (Table 3), of the 14 possible responses, eleven were negative and three were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the bin loader task (Table 4), corrective measures were suggested for the specific sub-tasks of lifting a piece from bin and arranging rack.

The PLIBEL checklist for the bin loader task (Table 5) reports a high percentage (~ 57- 62 %) of risk factors present for the neck, shoulder, upper back, and lower back, and a slightly lower percentage (~ 55 %) of risk factors present for the elbows, forearms, and hands. Several environmental and organizational modifying factors are present as well.

The NIOSH Lifting Equation was used to analyze the bin loading sub-task of manually picking material up from the bottom of the bin. The analysis (Table 6) for this task suggests a recommended weight limit of 3.8 pounds, given the assumed posture and frequency of lifts. Given that the typical weight of the material removed from the bins is about 10 pounds, it is determined that 46 per cent of the male population and 4 per cent of the female population can perform this task without an increased risk of low back pain.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the bin loading sub-task of manually picking material up from the bottom of the bin (Table 7). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 898 pounds, which exceeds the NIOSH Recommended Compression Limit of 770 pounds.

IIIB. CABLE CONNECTORS ONBOARD VESSEL

IIIB1. Cable Connection Process

Often referred to as switchboard installers, electricians identify routes and hook up wire cable ends to large switchboard units located throughout the ship. The process involves identifying specific cables and attachment locations.

1. Cable is routed in, around and through bottom of switchboard to the specific hook-up/connection lug. Once at the desired location, wire ties are used to secure cable.

Figure 5. Cable Connector Arranging Cable Prior to Connection

Figure 6. Cable Connector Changing/ Fixing Tools

2. Cable covering is removed and ends are stripped back to permit good attachment of cable ends. The lugs are then secured to the switchboard units.

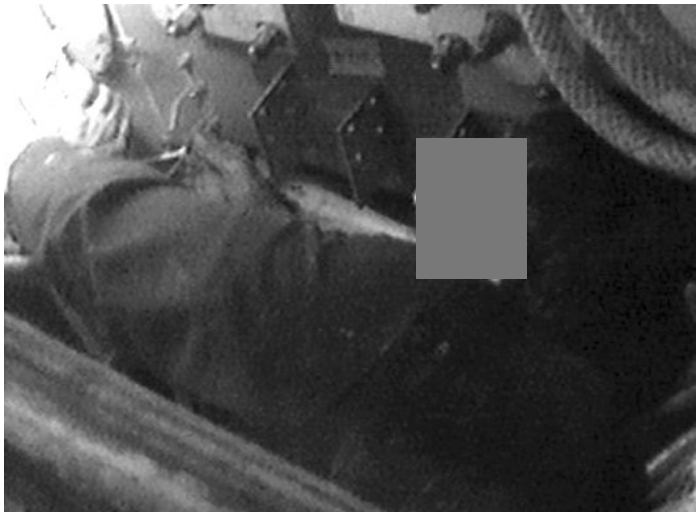


Figure 7. Cable Connector Tying Cable Off

Figure 8. Cable Connector Trimming Excess Ties

3. Hook-up is then inspected to assure proper arrangement has been achieved in the switchboard.

IIIB2. Ergonomic Risk Factors of Cable Connectors

During the switchboard hook-up process, static awkward postures of the upper extremities and trunk are common. Forceful exertions are performed often with the arms, wrist, and hands in a posture which places the body part at a biomechanical disadvantage. Work is frequently performed in a confined work area, which hampers the electrician's ability to use good body mechanics when performing work tasks. These constrained and awkward postures increase stress to the muscles being utilized thereby increasing fatigue and risk of developing a musculoskeletal disorder.

IIIB3. Ergonomic Analysis of Cable Connectors

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the cable connectors. A Rapid Upper Limb Assessment was conducted for the cable connectors (Table 8), analyzing four sub-tasks with unique postures. One of the four subtasks, arranging/tying cables, scored a 6 on a scale of 1 to 7 (investigate further and change soon). Another subtask, cable trimming, resulted in a score of 4 (investigate further). The final two subtasks of cable-tie trimming, and resting/ inspecting were determined to be "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the cable connector (Table 9) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as greater or equal to 80% of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be nearly static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 40.5. An SI score between 31-60 is correlated to an incidence rate of about 106 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at a substantially increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the cable connector (Table 10), of the 21 possible responses, twelve were negative and nine were positive. Again, negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the cable connector task (Table 11), no corrective measures were suggested for any the specific sub-tasks comprising cable connecting.

The PLIBEL checklist for the cable connector task (Table 12) reports a high percentage (~ 73 %) of risk factors present for the elbows, forearms, and hands, and a low to moderate percentage (~ 39 %) of risk factors present for the neck, shoulder, and upper back. Several environmental and organizational modifying factors are present as well.

IIIC. CABLE PULLERS ONBOARD VESSEL

IIIC1. Cable Pulling Process

Multiple lines of cable varying in length, size and weight are pulled by hand throughout areas of the ship. The larger cable pulls are performed by workers in groups numbering as high as 20. The size of the crew is largely dependent on the size, length, routing and final location of cable. Both 1.5-inch (approximate dimension) and 0.75-inch cable pulling was analyzed. Cable runs are located overhead, along bulkheads, and below deck plate level. All cable is secured into

cable trays and tagged whenever passing through a bulkhead or deck. When running from one deck to another, the cable passes through transits, which are later packed to assure an air- and water-tight seal. Following process was observed for the 1.5-inch cable and involves working at and below deck plate level:

1. Cable is routed fed through cable trays until final destination is reached. Photo below depicts this task being performed while sitting. This is due to the below deck plate location of cable tray.

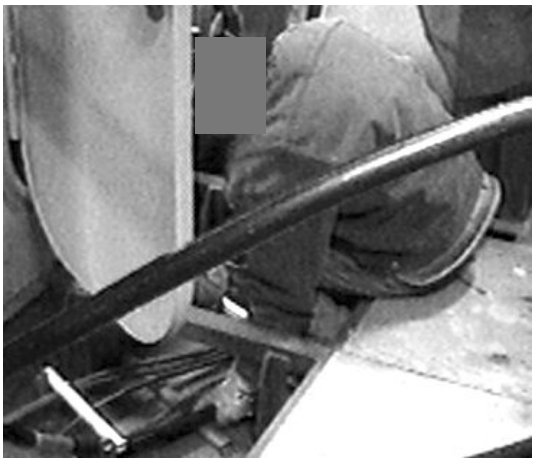


Figure 9. Cable Puller Sitting, Feeding 1.5" Diameter Cable Below Feet

2. Cable routing often involves manipulating cable already run through the tray and/or feeding through trays in hard to reach locations. The result is poor postures as depicted in the photo below.

Figure 10. Cable Puller Squatting, Feeding 1.5" Diameter Cable Below Feet

3. Once cable reaches the transit, or bulkhead oval (cutout), it is routed through the structure and secured using cable ties. This often requires forceful pulling while in an awkward posture.

4. When cable reaches its final destination process repeats. Employees take rest breaks as needed.

The identical process is used when pulling smaller cable, except that, one person is usually assigned to the job. The photos below depict the process performed when routing a 0.75-inch diameter cable through the overhead.

1. Cable is pulled through existing cable trays located in the overhead. The fact that it is difficult to orient the worker in relationship to the work space in the photo below is indicative of the confined areas cable pullers work in on a regular basis.

Figure 11. Cable Puller Standing, Adjusting 3/4" Diameter Cable Over Head

2. Cable must be fed through the cable trays. This is usually performed one tray at a time when space within the cable run is limited.

Figure 12. Cable Puller Standing, Feeding 3/4" Diameter Cable Over Head

3. During the process, the cable puller must frequently adjust the cable to permit it to pass through the cable tray. Figure 13 depicts the worker adjusting the cable in an overhead position. As the number of cables within the tray increases, the force required to pull the cable significantly increases. This often results in the workers reorienting themselves to obtain the necessary leverage to perform work task.

Figure 13. Cable Puller Standing, Pulling 3/4" Diameter Cable at Shoulder Height

4. Whenever cable passes through a bulkhead or deck it must be labeled for identification purposes. A label is pre-cut and marked. A small banding device is used to secure the label to the cable. Cables must also be tied to the cable tray utilizing plastic ties. Figure 14 depicts typical postures assumed when labeling and securing to cable trays.

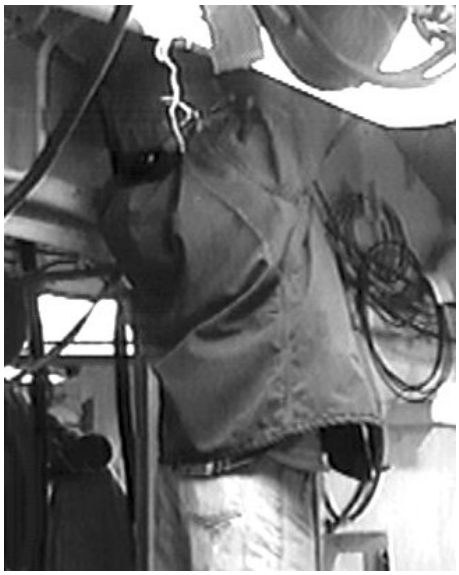


Figure 14. Cable Puller Standing, Tying Off 3/4" Diameter Cable Over Head

IIIC2. Ergonomic Risk Factors of Cable Pullers

Multiple risk factors were observed during the pulling process. Forceful exertions are common when handling the larger cable. This is significantly magnified due to postures assumed while engaged in the pulling process. When pulling cable below deck plate level, forward neck and trunk flexion is common. This is due to the location of cable trays and the specific route of the cable run. These postures can be static in nature with force being exerted while at a biomechanical disadvantage.

When pulling cable overhead, significant moment loads are placed on the shoulder and low back. Shoulder flexion and neck extension is common when pulling cable overhead with force being exerted at arm's length. This is a very physically demanding job with regard to the amount of force exerted.

IIIC3. Ergonomic Analysis of Cable Pullers Pulling 1.5-Inch Cable

Using several of the exposure assessment tools outlined previously, separate ergonomic analyses were performed for the cable pullers working with 1.5" diameter and .75 " diameter cable. A Rapid Upper Limb Assessment was conducted for the 1.5" diameter cable pulling task (Table 13), analyzing four sub-tasks with unique postures. Two of the four subtasks, feeding cable below feet while sitting and feeding cable below feet while squatting, scored 7's on a scale of 1 to 7 (investigate and change immediately). Another subtask, arranging cable in conduit, resulted in a score of 4 (investigate further). The final subtask of changing position was determined to be "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the cable connector (1.5" diameter) (Table 14) with the following results:

1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as equal to 60% of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were determined to be 2.4, but the task was rather static so the multiplier was set to 1.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 18. An SI score between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that 1.5"

cable pulling puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the 0.75" diameter cable pulling task, (Table 15), of the 18 possible responses, nine were negative and eight were positive. Again, negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the 1.5" diameter cable pulling task (Table 16), corrective measures were suggested for a number of the specific sub-tasks, including feeding cable below feet while sitting and squatting, changing position, and arranging cable in conduit.

The PLIBEL checklist for the 1.5" diameter cable pulling task (Table 17) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms, and hands, and a high percentage (~ 73 %) of risk factors present for the neck, shoulder, upper back, and lower back. A moderate percentage (~ 50 %) of risk factors were also reported for the feet, knees and hips. Several environmental and organizational modifying factors are present as well.

IIIC4. Ergonomic Analysis of Cable Pullers Pulling 0.75-Inch Cable

A Rapid Upper Limb Assessment was conducted for the 0.75" diameter cable pulling task (Table 18), analyzing four sub-tasks with unique postures. Two of the five subtasks, pulling cable and feeding cable, scored 7's (investigate and change immediately) on a scale of 1 to 7. Two other subtasks, adjusting cable and tying cables, resulted in scores of 5 (investigate further and change soon). The final subtask of changing position scored a 3 (investigate further).

A Strain Index analysis was performed for the cable connector (0.75" diameter) (Table 19) with the following results:

1) the Intensity of Exertion was rated as " Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as equal to 44% of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
3) the Efforts per Minute were determined to be 1.6, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 6.8. An SI score between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that

0.75" cable pulling puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the 0.75" diameter cable pulling task, (Table 20), of the 20 possible responses, fourteen were negative and five were positive. Again, negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the 0.75" diameter cable pulling task (Table 21), corrective measures were suggested for only one specific sub-task, tying cable.

The PLIBEL checklist for the 0.75" diameter cable pulling task (Table 22) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms, and hands, and a moderate to high percentage (~ 58 %) of risk factors present for the neck, shoulder, upper back. Lower percentages of risk factors were also reported for the feet, knees and hips (~ 50 %), and low back (~ 53 %). Several environmental and organizational modifying factors are present as well.

IIID. EQUIPMENT LOAD-IN BY SHIPBOARD RIGGERS

IIID1. Equipment Load-In Process

Equipment is lifted off of the transportation vehicle via a large gantry crane and lowered into the ship. Depending on the final location of equipment and location of access hole, the degree of manual manipulation of the object will vary. Two groups of riggers exist within the shipyard. Those who work with the gantry crane operators are often referred to as dock riggers. Their job responsibilities include rigging loads safely and being in visual and/or verbal contact with the crane operator. Some truck drivers also rig up lifts. The employees who perform work tasks within the ship, i.e. moving equipment through compartments, are often referred to as shipboard riggers. Once the equipment is unhooked from the crane, shipboard riggers are responsible for getting the equipment/item to its final position. Comparing the dock and shipboard riggers, by far the shipboard employees perform the more physically demanding group of job tasks. Overall processes in transferring equipment between the dock riggers outside the vessel to shipboard riggers are as follows:

1. Equipment is lowered into an access hole located on the bow. A tag line is used to safely guide the load down to the shipboard riggers located below deck.

Figure 15. Lowering Equipment Through Hatch

2. Figure 16 depicts shipboard riggers rolling equipment into the general vicinity of its final destination. Low cart rollers are very effective for moving equipment over flat decks with no lips or protrusions. Unfortunately, only a few areas are suitable for this mode of transport.

Figure 16. Rolling Equipment in on Low Profile Cart

3. Once the equipment or item is close to its final destination, or needs to move off of the low profile cart, it is slid across the deck as depicted in Figure 17. Again, the ability to perform this task is dependent on floor covering and the coefficient of friction between the item and the floor.

Figure 17. Sliding Equipment Off Cart

4. When feasible, shipboard riggers place a one-inch pipe under the equipment permitting it to be rolled with less effort.

Figure 18. Rolling Equipment in on Pipe Rollers

5. To place or remove pipe roller from underneath the equipment, the item being moved must be tilted on one end, which permits the roller device to be set. Figure 19 depicts this task being performed.

Figure 19. Tilting Equipment to Insert Pipe Rollers

6. Once the equipment or item is in place, the process repeats until truck is unloaded.

IIID2. Ergonomic Risk Factors for Shipboard Riggers During Equipment Load-In

Shipboard riggers perform forceful manual material handling on a frequent basis. This includes forceful push/pull, lift and, at times, carry. These tasks are often performed while in awkward postures (shoulder and wrist extension while in a kneeling posture with a forward flexed trunk in axial rotation with a lateral bend). These poor postures greatly increase the force required to perform work task. The magnitude of the risk factors is determined by the ship and deck landing points, the item being moved, the ship and deck configuration and the final location of equipment. At times, shipboard riggers carry heavy mechanical lift assist devices on board to get heavier equipment through shipboard doorways.

IIID3. Ergonomic Analysis of Shipboard Riggers During Equipment Load-In

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the shipboard riggers during equipment load-in. A Rapid Upper Limb Assessment was conducted for the shipboard riggers (Table 22), analyzing six sub-tasks with unique postures. Two of the six subtasks, rolling equipment on pipe rollers and tilting equipment, scored 7's (investigate and change immediately) on a scale of 1 to 7. Another subtask, sliding equipment, resulted in a score of 6 (investigate further and change soon). Two other subtasks, lowering equipment through hatch and rolling equipment on low profile cart, resulted in scores of at least

3 (investigate further). The final subtask of waiting for the new load was the only one deemed "acceptable" with a score of one out of seven.

A Strain Index analysis was performed for the bin loader (Table 23) with the following results:

1) the Intensity of Exertion was rated as " Hard" and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as 51 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be 2.2, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Good," resulting in a multiplier of 1.0 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 4.5. An SI score SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the shipboard rigger at an minimal risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard rigger (Table 24), of the 16 possible responses, eight were negative and eight were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard rigger equipment loading task (Table 25), corrective measures were suggested for the specific sub-tasks of rolling equipment on pipe rollers, tilting equipment, sliding equipment, and rolling equipment on low profile cart.

The PLIBEL checklist for the shipboard rigger equipment loading task (Table 26) reports a high percentage (64%) of risk factors present for the elbows, forearms, and hands. Slightly lower percentages of risk factors present for the neck, shoulder, upper back (~ 57 %), and low back (~50%) were also reported. Several environmental and organizational modifying factors are present as well.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shipboard rigger equipment loading subtask of tilting equipment (Table 28). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 789 pounds, which exceeds the NIOSH Recommended Compression Limit of 770 pounds.

IIIE. INSULATION INSTALLATION WORKERS ONBOARD VESSEL

IIIE1. Insulation Installation Process

Insulators usually work in teams consisting of one installer and one cutter. The installer measures the area to be covered and relays this information to the cutter, who measures, marks and cuts the piece of insulation to size. The piece is then handed up or over to the installer who pushes the insulation into place, piercing the insulation material onto the insulation stud. The installer then installs a cap over the end of the stud securing it with a hammer strike. Installers and cutters will trade places from day to day. It is common for installers to work off of stepladders when performing overhead and some bulkhead installation. Cutters usually set up makeshift workbenches using several boxes of the insulation and/or sawhorses. Most of the insulation is a foam type of material, however, some fiberglass is still used. Sheets are usually 2 feet by 4 feet.

Cutters measure marks and cut pieces of insulation to size. The piece is then handed up or over to the installer.

1. Figure 20 depicts the cutter measuring and marking a sheet of foam insulation from information received from the installer.

Figure 20. Insulation Cutter Measuring Insulation

2. Insulation is then cut using a slight sawing motion with a special knife.

Figure 21. Insulator Cutter Using Knife to Cut Insulation

3. Once the piece has been cut to size, it is handed up or over to the installer.

Figure 22. Insulator Cutter Moving Insulation

4. Cutter then sets up another piece to be fitted and the process repeats.

Figure 23. Insulator Cutter Passing Insulation to Installer

Installers measure the area to be covered and verbally relay information to cutter. Once insulation has been cut to size, it is secured to the overhead and/or bulkhead using stud caps, which must be snapped or hammered into place.

1. Cut insulation is fit into area to be covered.

Figure 24. Insulation Installer Placing Insulation Over Head

2. Installer measures area to be cut.

Figure 25 .Insulation Installer Measuring Insulation

3. Insulation is trimmed (if necessary) and stud or tie holes are cut.

Figure 26. Insulation Installer Cutting Insulation

4. Stud caps are then secured by a hammer and process repeats.

Figure 27. Insulation Installer Hammering Stud Caps Down

IIIE2. Ergonomic Risk Factors for Insulation Cutters

The key risk factors for insulation cutters are moderate forward head and neck postures. These postures are assumed when transferring measurements to the insulation piece and during the cutting process. Depending on the grip used on the knife, ulnar deviation of the wrist is common; however, force exerted is light.

IIIE3. Ergonomic Risk Factors for Insulation Installers

Working at or above shoulder level is common when installing insulation in the overhead. Shoulder flexion with the wrist in extension is common when performing overhead work. The neck is also in significant extension when looking and working in the overhead. While force exertions are minimal, stress created by awkward postures of the upper extremities and neck is significant. If the area to be covered is obstructed by piping, ventilation runs, and/or equipment, awkward postures of the trunk are assumed.

IIIE4. Ergonomic Analysis of Insulation Cutters

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the insulation cutters. A Rapid Upper Limb Assessment was conducted for the insulation cutters (Table 29), analyzing five sub-tasks with unique postures. One of the five subtasks, cutting insulation, scored a 5 (investigate further and change soon) on a scale of 1 to 7.

Another subtask, measuring insulation, resulted in a score of 3 (investigate further). The final subtasks of changing tools, passing insulation, and moving insulation, were deemed "acceptable" with a scores of two out of seven.

A Strain Index analysis was performed for the insulation cutter (Table 30) with the following results:

1) the Intensity of Exertion was rated as "Light" and given a multiplier score of 1 on a scale of 1 to 13
2) the Duration of the task was rated as 41 % of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be 2.4, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 1.1. An SI score SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an minimal risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the insulation cutter (Table 31), of the 22 possible responses, fourteen were negative and eight were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the insulation cutter (Table 32), corrective measures were only suggested for the specific sub-task of cutting insulation.

The PLIBEL checklist for the insulation cutter (Table 33) reports a moderate percentage (46%) of risk factors present for the elbows, forearms, and hands. Several environmental and organizational modifying factors are present as well.

IIIE5. Ergonomic Analysis of Insulation Installers

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the insulation installers. A Rapid Upper Limb Assessment was conducted for the insulation installers (Table 34), analyzing six sub-tasks with unique postures. Four of the six subtasks, placing insulation overhead, measuring insulation overhead, trimming insulation/ cutting tie holes, and hammering stud caps, scored at least 5's (investigate further and change

soon) on a scale of 1 to 7. Another subtask, repositioning body/ ladder, resulted in a score of 3 (investigate further). The final subtask of waiting for the cutter was the only one deemed "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the insulation installer (Table 35) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13
2) the Duration of the task was rated as 65 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be 2, but since they were rather static, a multiplier of 1.0 on a scale of 0.5 to 3.0 was assigned
4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 12. An SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the insulation installer at moderate risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the insulation installer (Table 36), of the 22 possible responses, fifteen were negative and seven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the insulation installer task (Table 37), corrective measures were suggested for the specific sub-tasks of placing insulation overhead, measuring insulation overhead, trimming insulation/ cutting tie holes, and hammering stud caps.

The PLIBEL checklist for the insulation installer task (Table 38) reports a high percentage (63%) of risk factors present for the feet, knees and hips. Slightly lower percentages of risk factors present for the low back (~ 57 %), neck, shoulder, upper back (~ 50%), and elbows, forearms, and hands (~ 46%) were also reported. Several environmental and organizational modifying factors are present as well.

IIIF. WIRE WELDING IN THE PANEL LINE ASSEMBLY AREA

IIIF1. Wire Welding in Panel Line Process

Welders working in the panel line building are responsible for welding sheets and other structural members to form bulkheads, decks and overhead units. Items to be welded have been tacked into place by the shipfitters. If necessary, welders grind the area to remove any foreign debris and using semi-automatic welding equipment performs the welding operation. Once a bead has been run, it is cleaned using a slag hammer, offset wire brush or other pneumatic tool. Most work in the panel line is performed in the downward position. It is common for welders to sit, kneel, crouch, bend and even lay down on the steel when welding.

Figure 28 shows welder grinding areas prior to welding process. Posture is typical of those assumed by welders in the panel line building.

Figure 28. Panel Line Welder Grinding Prior to Welding

A welder assumes a forward flexed posture on one knee to perform welding tasks. Again this is a very typical posture assumed by welders working at deck plate level.

Figure 29. Panel Line Welder Wire Welding

Once the grinding and welding process has been accomplished, the welder rearranges the temporary ventilation (sucker tube), air hose, and welding leads for the next job. Welders are required to position sucker tubes to remove welding fumes/smoke.

Figure 30. Panel Line Welder Rearranging Tools

Figure 31 shows welder changing position for other welding tasks.

Figure 31. Panel Line Welder Changing Position

IIIF2. Ergonomic Risk Factors for Wire Welders in the Panel Line Assembly Area

Key risk factors include static awkward postures of the back, neck and arms. Many of these postures could be considered extreme, as many of the joints are at difficult or extreme angles, which increases force requirements and heighten muscle fatigue. Static awkward postures of the wrist and hand (wrist extension while in ulnar deviation) can be assumed when holding onto semi-automatic welding gun. While welders are instructed not to snap the neck forward when lowering their welding hood, several such actions were observed. This places high shear loads on the cervical discs. Some external contact forces are realized in the knees, hands and arms. Static kneeling places high stress on the patella and can be a key risk factor in the development of patella-femoral pain.

IIIF3. Ergonomic Analysis of Wire Welders in the Panel Line Assembly Area

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the panel line welder. A Rapid Upper Limb Assessment was conducted for the panel line welder (Table 39), analyzing six sub-tasks with unique postures. One of the six subtasks, wire welding while kneeling, scored a 7 (investigate and change immediately) on a scale of 1 to 7. Another subtask, grinding crouched or kneeling, resulted in a score of 5 (investigate further and change soon). Three other subtasks, inspecting, re-arranging equipment, and re-positioning body, resulted in scores of 3 (investigate further). The final subtask of changing tool was deemed “acceptable” with a score of two out of seven.

A Strain Index analysis was performed for the panel line wire welder (Table 40) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3 on a scale of 1 to 13
2) the Duration of the task was rated as 54 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be 3, but since the exertions were nearly static, the multiplier was set to 1.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 27. An SI score between 5-30 is correlated to an incidence rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the panel line welder (Table 41), of the 21 possible responses, twelve were negative and nine were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the panel line welder task (Table 42), corrective measures were suggested for the specific sub-tasks of inspecting, wire welding kneeling, re-arranging equipment, and changing position.

The PLIBEL checklist for the panel line welder task (Table 43) reports a moderately high percentage of risk factors present for the elbows, forearms, and hands (~ 55 %) and slightly lower percentages for the neck, shoulder, upper back (~ 50 %), and lower back (~ 48 %). Several environmental and organizational modifying factors are present as well.

IIIG. SHIPBOARD TANK GRINDING

IIIG1. Shipboard Tank Grinding Process

Primary responsibilities include removing paint, rust and other foreign objects from tanks, the bilge, bulkheads, etc. The main purpose is to prepare surface for painting. In some areas all paint is removed while in others a feathered edge is created. Tank grinders use multiple pneumatic tools, depending on specific task to be completed and available work space. The most common pneumatic tools used include the 3- and 5-inch disc sanders, offset wire brush and

needle gun. After the area has been ground, it is cleaned using various cleaning solutions.

1. Figure 32 shows a tank grinder utilizing a 5-inch disc sander, which is one of the most commonly, used tools within the shipyard. The tool itself is a modified drill with backing pad attached.

Figure 32. Tank Grinder Using 5 inch Offset Grinder

2. A 3-inch disc grinder is used on the underneath sides of stiffeners and other structural members as well as in tight/hard to reach spaces.

Figure 33. Tank Grinder Using 3 inch Offset Grinder

3. Figure 34 shows an offset wire brush being used. This tool is used commonly on pipes, in corners on welds, etc.

Figure 34. Tank Grinder Using Wire Brush

4. A needle gun is commonly used to chip off paint and/or slag from welds. Figure 35 shows a needle gun in use.

Figure 35. Tank Grinder Using Needle Gun Overhead

IIIG2. Ergonomic Risk Factors for Shipboard Tank Grinding

Key risk factors that were observed with the tank grinders were the awkward static postures of the trunk and upper extremities assumed while performing job tasks. Work postures are at times dictated by the amount of space available for the employee to perform job tasks. Static gripping of pneumatic or vibrating tools is performed on a regular basis. Bi-planar wrist postures (flexion or extension with ulnar deviation) are common. Employees must wear full-face negative pressure respirators while engaged. Some external contact forces are realized in the knees, hands and arms. Static kneeling places high stress on the patella and is a key risk factor in the development of patella-femoral pain.

IIIG3. Ergonomic Analysis of Shipboard Tank Grinding

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the shipboard tank grinder. A Rapid Upper Limb Assessment was conducted for the shipboard tank grinder (Table 44), analyzing six sub-tasks with unique postures and forces. Two of the six subtasks, grinding with a 3 inch grinder overhead and using wire brush, scored 7's (investigate and change immediately) on a scale of 1 to 7. Two other subtasks, grinding with 5 inch grinder and using needlegun, resulted in scores of at least 5 (investigate further and change soon). The final two subtasks of changing tool and changing grinding pad resulted in scores of 3 (investigate further).

A Strain Index analysis was performed for the shipboard tank grinder (Table 45) with the following results:

1) the Intensity of Exertion was rated as “Hard” and given a multiplier score of 6 on a scale of 1 to 13
2) the Duration of the task was rated as 91 % of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be nearly static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 2 and 4 hours, resulting in a multiplier of 0.75 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 60.8. An SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the worker at an extremely increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist

to the shipboard tank grinder (Table 46), of the 22 possible responses, fourteen were negative and eight were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard tank grinder (Table 47), corrective measures were suggested for the specific sub-tasks of grinding with 5 inch and 3 inch grinders, wire brushing, and using the needle gun.

The PLIBEL checklist for the bin loader task (Table 48) reports a very high percentage (~ 82 %) of risk factors present for the elbows, forearms, and hands and a high percentage (~ 63 %) for the feet, knees and hips. Slightly lower percentages of risk factors are present for the neck, shoulder, upper back (~ 54 %), and lower back (~ 53 %). Several environmental and organizational modifying factors are present as well.

IV. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in press.

IVA. PANEL LINE BIN LOADING BY MATERIAL HANDLERS POSSIBLE INTERVENTIONS

Possible interventions for the bin loaders in the panel line assembly area include adjustable bins that raise and tilt the load towards the worker. Many inexpensive models of this type are commercially available. A hook-like tool for grasping individual workpieces may also help to bring the load closer to the material handler and also reduce the need for pinch-grip hand postures. Work practices of pre-sorting heavier items and emptying them by forklift onto a rotatable table top before handling may also be feasible.

IVB. SHIPBOARD CABLE CONNECTORS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard cable connectors include work practices which reduce the amount of cable preparation (stripping, tying etc...) at the switchboard, where the confined space limits work movements and postures. The use and maintenance of specialized cable tools may also reduce grip and other upper extremity forces.

IVC. SHIPBOARD CABLE PULLERS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard cable pullers include work rotation among pullers so that time spent in postures involving overhead work, kneeling, and back flexion are minimized and work practices to begin pulls in the middle of the cable rather than at the end (which requires pulling the entire length of cable in one pull). Semi-automated cable pulling systems are also commercially available and may be able to be integrated into the current manual pulling method.

IVD. EQUIPMENT LOAD-IN BY SHIPBOARD RIGGERS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard riggers during equipment load-in include the work practice of preparing the temporary deck surface to reduce the number of uneven plate and plywood surfaces that inhibit cart travel. Modified, low- profile ball bearing type carts or carts with lowered axles and adjustable wheels located outside the perimeter of the transported equipment may then be used to maneuver taller pieces of equipment into place. Such carts should reduce or eliminate the need for tilting the equipment on and off the pipe rollers and may also be able to be designed to allow for a smooth placement of the equipment into the retaining bracket.

IVE. SHIPBOARD INSULATORS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard insulators (cutters) include angled knives to maintain neutral wrist postures. Possible interventions for the shipboard insulators (installers) include an alternate insulation securing process involving semi-automatic stud guns or re-designed knives and hammers. Work rotation between the cutters and installers may also reduce the time spent in overhead postures by the worker performing the installation task.

IVF. PANEL LINE WELDING POSSIBLE INTERVENTIONS

Possible interventions for the panel line welders include the use of low profile, wheeled carts as movable seats for the welders to reduce back flexion and the need to assume kneeling postures. Such carts may be able to be custom designed to include upper body supports and knee supports that allow a variety of postures, such as semi-sitting or kneeling and leaning forward. Knee pads and thigh-supports to prevent overflexion of the knees during squatting are also commercially available.

IVG. SHIPBOARD TANK GRINDERS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard tank grinders include lighter tools that induce less vibration and the use of support devices such as spring returns for areas where extended vertical grinding is required. Process changes (e.g. weldable primer, more efficient and clean welding processes) to reduce the amount of required grinding may also be explored. Portable, self-contained abrasive blasting units may also be able to be used instead of manual grinding in some cases.

V. CONCLUSIONS AND RECOMMENDATIONS

Seven work processes within Bath Iron Works were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. These processes included panel line bin un-loading, shipboard cable connecting, shipboard cable pulling, shipboard equipment load-in, shipboard insulation cutting and installing, panel line welding, and shipboard tank grinding. In

each process, certain work elements were found to be associated with one or more factors, including excessive force, constrained or awkward postures, contact stresses, vibration, and repetitive motions.

It is recommended that further action may be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. It is recommended that ergonomic interventions may be implemented at Bath Iron Works facilities to minimize hazards in the identified job tasks.

VI. REFERENCES

Kemmlert, K. A Method Assigned for the Identification of Ergonomic Hazards – PLIBEL. *Applied Ergonomics,* 1995, 26(3):199-211.

Lifshitz, Y. and T. Armstrong. A Design Checklist for Control and Prediction of Cumulative Trauma Disorders in Hand Intensive Manual Jobs. *Proceedings of the 30th Annual Meeting of Human Factors Society*,1986, 837-841.

Louhevaara, V. and T. Suurnäkki. *OWAS: A Method for the Evaluation of Postural Load during Work.* Training Publication No. 11, Institute of Occupational Health, Helsinki, Finland, 1992.

McAtamney, L., and E. N. Corlett. RULA: A Survey Method for the Investigation of Work-Related Upper Limb Disorders, *Applied Ergonomics*, 1993, 24(2):91-99.

Moore, J. S., and A. Garg. The Strain Index: A Proposed Method to Analyze Jobs for Risk of Distal Upper Extremity Disorders, *American Industrial Hygiene Association Journal*, 1995, 56:443-458.

University of Michigan Software, *3D Static Strength Prediction Program Version 4.0*, 3003 State St., #2071 Ann Arbor, MI 48109-1280, Copyright 1997 The Regents of The University of Michigan.

APPENDIX

TABLES

A1. Bin Loading

Table 1. Bin Loading RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin Loading

RULA: Posture Sampling Results										
RULA Component	**Frames # 30690 Walk back to bins**		**Frame # 30750 Lift piece from bin**		**Frame # 31140 Carry piece**		**Frame # 33690 Rack arranging**		**Frame # 34890 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	neut	1	mod flex	3	neut	1	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	add	1	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	ext	2	ext	2	ext	2	neut	1
Wrist Deviation	neut	0	ulnar	1	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		1		1		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		2		1		1		0

Table 1. Bin Loading RULA (continued)

RULA Component	**Frames # 22890 Walk back to bins**		**Frame # 25050 Lift piece from bin**		**Frame # 23460 Carry piece**		**Frame # 133770 Rack arranging**		**Frame # 25530 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	sl flx	2	ext	4	sl flx	2	mod flx	3	neut	1
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	hyp flx	4	neut	1	mod flx	3	neut	1
Trunk Twist (+1)		0		1		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		1		1		1
Total RULA Score	**3**		**7**		**4**		**3**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 2. Bin Loaders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin Loading

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13
Intensity of Exertion Multiplier					**3**

Table 2. Bin Loaders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 204 (sec)/ 268(sec) = 76	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	**4**	**2.0**
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and circle the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = 100 x number of exertions / Total observation time (min) = 69 /4.5 = 11.2	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	**3**	**1.5**
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.5**

Table 2. Bin Loaders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Circle the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 2. Bin Loaders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Circle the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	**3**	**0.75**
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion **3 X**	**Duration of Exertion** **2 X**	**Efforts per Minute** **1.5 X**	**Hand/ Wrist Posture** **1.5 X**	**Speed of Work** **1 X**	**Duration of Task** **.75**	**=**	**SI Score** **10.1**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 3. Bin loaders UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin loading

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	n/a	n/a
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	11 (79%)	3 (21%)

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 4. Bin Loaders OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin loading

Risk Factor	**Work Phase1 Walk back to bins**	**Work Phase 2 Lift piece from bin**	**Work Phase 3 Carry piece**	**Work Phase 4 Rack arranging**	**Work Phase 5 Rest**
TOTAL Combination Posture Score	**1**	**2**	**1**	**2**	**1**
Common Posture Combinations (collapsed across work phases)					
Back	1	4	1	2	1
Arms	1	1	1	1	1
Legs	7	2	7	2	2
Posture Repetition (% of working time)	42	48	26	2	8
BACK % of Working Time SCORE	1	3	1	1	1
ARMS % of Working Time SCORE	1	1	1	1	1
LEGS % of Working Time SCORE	1	1	1	1	1

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 4. Bin Loaders OWAS (continued)

Risk Factor	**Work Phase1 Walk back to bins**	**Work Phase 2 Lift piece from bin**	**Work Phase 3 Carry piece**	**Work Phase 4 Rack arranging**	**Work Phase 5 Rest**
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	4	1	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	7	2	7	2	2
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	1	2	2	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	16	48	26	2	8

Table 5. Bin Loaders PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin Loading

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	**Body Regions**				
	Neck, Shoulder, Upper Back	**Elbows, Forearm, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no chance to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 5. Bin Loaders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 5. Bin Loaders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**16**	**6**	**1**	**1**	**12**
PERCENTAGE	**61.5**	**54.5**	**12.5**	**12.5**	**57.1**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**4**				
PERCENTAGE	**40.0**				

Table 6. Bin Loaders NIOSH Lifting Equation Analysis

NIOSH Lifting Equation
(Waters, Putz-Anderson, Garg, and Fine, 1993)

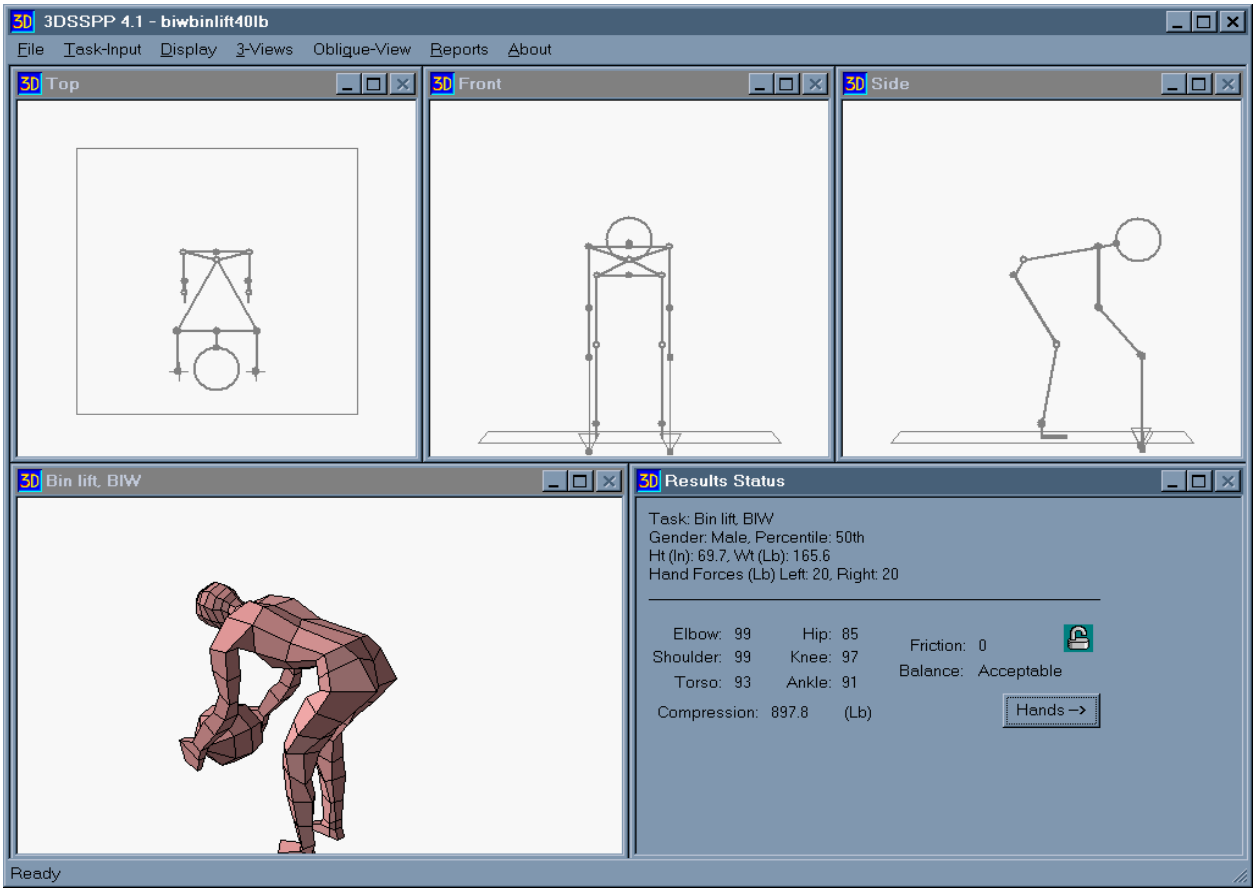
Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin Loading

RESULTS	**ORIGIN**	**DESTINATION**
Recommended Weight Limit (RWL)	3.8 pounds	9.3 pounds
Lifting Index, LI (RWL/Load)	2.63	
Population Capable	Male = 46 % Capable Female = 4 % Capable	
ORIGIN VARIABLE	**ORIGIN VALUE**	**ORIGIN MULTIPLIER**
Horizontal Location, H	24 inches	0.42
Vertical Location, V	5 inches	0.81
Travel Distance, D	31 inches	0.88
Asymmetric Angle, A	0 degrees	1.00
Frequency, F	10 lifts/minute	0.26
Hand to Object Coupling, C	Fair	1.00
DESTINATION VARIABLE	**DESTINATION VALUE**	**DESTINATION MULTIPLIER**
Horizontal Location, H	12 inches	0.83
Vertical Location, V	36 inches	0.96
Travel Distance, D	31 inches	0.88
Asymmetric Angle, A	0 degrees	1.00
Frequency, F	10 lifts/minute	0.26
Hand to Object Coupling, C	Fair	1.00
Duration: 2 hours	**Average Object Weight: 10 pounds**	**Maximum Object Weight: 40 pounds**

Table 7. Bin Loader 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line assembly	Bin Loading
Work Elements: **Bin Loading in Panel Line Area** **Frame Components**		**Disc Compression (lbs) @ L5/S1** **(Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)**	
Bin loader picks up material from bottom of bin, approximate weight 40 pounds (frame # 30750)		898 pounds	



A2. Cable Connectors

Table 8. Cable Connectors RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Connecting

RULA Component	**Frames #169620, 174300 Arrange/tie cables**		**Frame # 176340 Change/ fix tools**		**Frame # 197490 Trim cable-ties**		**Frame # 192810 Rest/ Inspect**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		1		0
Upper Arm Abducted (+1)		0		0		0		0
Arm supported, leaning (-1)		-1		-1		-1		0
Elbow Extension/ Flexion	neut	2	neut	2	flx	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	mod med	1	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	ext	2	neut	1
Wrist Deviation	rad	1	neut	0	ulnar	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		0		1		0

Table 8. Cable Connectors RULA (continued)

RULA Component	Frames #169620, 174300 Arrange/tie cables		Frame # 176340 Change/ fix tools		Frame # 197490 Trim cable-ties		Frame # 192810 Rest/ Inspect	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		1		1		1		1
Neck Twist (+1)		1		1		1		0
Neck Side-Bent (+1)		1		1		1		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		1		1		1		0
Trunk Side Bend (+1)		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		0		1		0
Total RULA Score	**6**		**2**		**4**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 9. Cable Connectors Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Connecting

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3.0**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 9. Cable Connectors Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 889 (sec)/ 1075(sec) = 83	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	**5**	**3.0**
Duration of Exertion Multiplier			**3.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = nearly static, so set to 3.0	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	**5**	**3.0**
Efforts per Minute Multiplier			**3.0**

Table 9. Cable Connectors Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM** ***(observed pace is divided by MTM's predicted pace and expressed as %)***	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 9. Cable Connectors Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 4-8 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**3.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**40.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 10. Cable Connectors UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Connecting

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?	N	
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (cutter)
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**12 (57%)**	**9 (43%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 11. Cable Connectors OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Connecting

Risk Factor	**Work Phase1 Arrange/ tie cables**	**Work Phase 2 Change/ fix tools**	**Work Phase 3 Trim cable ties**	**Work Phase 4 Rest/ Inspect**
TOTAL Combination Posture Score	**1**	**1**	**1**	**1**
Common Posture Combinations (collapsed across work phases)				
Back	3	1		
Arms	1	1		
Legs	1	1		
Posture Repetition (% of working time)	83	5		
BACK % of Working Time SCORE	3	1		
ARMS % of Working Time SCORE	1	1		
LEGS % of Working Time SCORE	1	1		
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately				

Table 11. Cable Connectors OWAS (continued)

Risk Factor	**Work Phase1** **Arrange/ tie cables**	**Work Phase 2** **Change/ fix tools**	**Work Phase 3** **Trim cable ties**	**Work Phase 4** **Rest/ Inspect**
Posture				
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	3	3	3	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	1	1	1
Load/ Use of Force				
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)				
3 = weight or force > 20 kg (>44 lbs)				
Phase Repetition				
% of working time (0,10,20,30,40,50,60,70,80,90,100)	77	4	2	5

Table 12. Cable Connectors PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Connecting

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	**Body Regions**				
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	N				N
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 12. Cable Connectors PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 12. Cable Connectors PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearm, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**10**	**8**	**2**	**2**	**5**
PERCENTAGE	**38.5**	**72.7**	**25**	**25**	**23.8**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**2**				
PERCENTAGE	**20.0**				

A3. Cable Pulling

Table 13. Cable Pull (1.5") RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/Time	Facility	Area/Shop	Task
4/17/00	BIW	Shipboard	Cable Pulling (1.5")

RULA: Posture Sampling Results										
RULA Component	**Frames # 22890 Feed cable below feet, sitting**		**Frame # 25050 Feed cable below feet squatting**		**Frame # 23460 Change position**		**Frame # 133770 Arrange cable in conduit**		**Frame # 25530 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	neut	2	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	lat	1	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	1	ext	2	neut	1
Wrist Deviation	ulnar	1	ulnar	1	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		0		1		0

Table 13. Cable Pull (1.5") RULA (continued)

RULA Component	**Frames # 22890 Feed cable below feet, sitting**		**Frame # 25050 Feed cable below feet squatting**		**Frame # 23460 Change position**		**Frame # 133770 Arrange cable in conduit**		**Frame # 22409 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	sl flx	2	sl flx	2	neut	1	sl flx	2	sl flx	2
Neck Twist (+1)		1		1		0		1		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	sl flx	2	mod flx	3	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		1		1		0		0		0
Trunk Side Bend (+1)		1		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		3		1		1		0
Total RULA Score	**7**		**7**		**2**		**4**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 14. Cable Pullers (1.5 inch diameter) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Pulling (1.5")

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	**30 - 49%**	**4 - 5**	**obvious effort; unchanged facial expression**	**3**	**6.0**
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 14. Cable Pullers (1.5 inch diameter) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 91(sec)/ 152 (sec) = 60	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	**4**	**2.0**
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 6/2.5 = 2.4, but rather static so set multiplier to 1.0	< 4	1	0.5
	4 - 8	**2**	**1.0**
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 14. Cable Pullers (1.5 inch diameter) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 14. Cable Pullers (1.5 inch diameter) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 4-8 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
6.0 X	**2.0 X**	**1.0 X**	**1.5 X**	**1.0 X**	**1.0**		**18**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 15. Cable Pullers (1.5 inch diameter) UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable pulling (1.5")

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**9 (53%)**	**8 (47%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 16. Cable Pullers (1.5 inch diameter) OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Pulling (1.5")

Risk Factor	**Work Phase1** Feed cable below feet, sitting	**Work Phase 2** Feed cable below feet squatting	**Work Phase 3** Change position	**Work Phase 4** Arrange cable in conduit	**Work Phase 5** Rest
TOTAL Combination Posture Score	**3**	**2**	**2**	**2**	**1**
Common Posture Combinations (collapsed across work phases)					
Back	4	2	2	2	1
Arms	1	1	1	1	1
Legs	1	4	7	1	1
Posture Repetition (% of working time)	16	26	7	11	3
BACK % of Working Time SCORE	2	1	1	1	1
ARMS % of Working Time SCORE	1	1	1	1	1
LEGS % of Working Time SCORE	1	2	1	1	1

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 16. Cable Pullers (1.5 inch diameter) OWAS (continued)

Risk Factor	**Work Phase1 Feed cable below feet, sitting**	**Work Phase 2 Feed cable below feet squatting**	**Work Phase 3 Change position**	**Work Phase 4 Arrange cable in conduit**	**Work Phase 5 Rest**
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	4	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	4	7	1	1
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	2	2	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	16	26	7	11	3

Table 17. Cable Pullers (1.5 inch diameter) PLIBEL

PLIBEL Checklist
Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task
4/17/00	BIW	Shipboard	Cable Pulling (1.5")

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, Upper Back	Elbows, Forearm, Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 17. Cable Pullers (1.5 inch diameter) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 17. Cable Pullers (1.5 inch diameter) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearm, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**19**	**9**	**4**	**4**	**15**
PERCENTAGE	**73.1**	**81.8**	**50**	**50**	**71.4**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	**4**				
PERCENTAGE	**40.0**				

Table 18. Cable Pull (3/4 inch diameter) RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
4/17/00	*BIW*	*Shipboard*	Cable Pulling (3/4")

RULA: Posture Sampling Results

RULA Component	**Frames # 115920-116820 Pull cable**		**Frame # 128130 Feed cable**		**Frame # 134490 Change position**		**Frame # 133770 Adjusting cable**		**Frame # 22409 Tie cables**		**Frame # 130170 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	mod flex	3	hyp flex	4	mod flex	3	hyp flex	4	hyp flex	4	neut	1
Shoulder is Raised (+1)		0		1		0		1		1		0
Upper Arm Abducted (+1)		1		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	ext	1	neut	2	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	mod abd	1	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	lat	1	mod med	1	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	neut	1	ext	2	ext	2	neut	1
Wrist Deviation	ulnar	1	ulnar	1	neut	0	ulnar	1	ulnar	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		2		1		1		1		0

Table 18. Cable Pull (3/4 inch diameter) RULA (continued)

RULA Component	**Frames # 115920-116820 Pull cable**		**Frame # 128130 Feed cable**		**Frame # 134490 Change position**		**Frame # 22080 Adjusting cable**		**Frame # 22409 Tie cables**		**Frame # 18000 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	neut	1	ext	4	ext	4	ext	4	ext	4	sl flx	2
Neck Twist (+1)		1		1		1		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		1		1		1		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		2		1		1		1		0
Total RULA Score	7		7		3		5		5		1	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 19. Cable Pullers (3/4 inch diameter) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Pull 3/4"

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 19. Cable Pullers (3/4 inch diameter) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 330(sec)/ 745 (sec) = 44	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**1.5**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 20/ 12.45 = 1.6	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 19. Cable Pullers (3/4 inch diameter) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 19. Cable Pullers (3/4 inch diameter) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
6.0 X	**1.5 X**	**0.5 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**6.8**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 20. Cable Pullers (3/4 inch diameter) UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Pull 3/4"

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors_____	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**14 (74%)**	**5 (26%)**

Table 21. Cable Pullers (3/4 inch diameter) OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Pulling (3/4")

Risk Factor	**Work Phase1** **Pull cable**	**Work Phase 2** **Feed cable**	**Work Phase 3** **Change position**	**Work Phase 4** **Adjust cable**	**Work Phase 5** **Tie cables**	**Work Phase 6** **Rest**
TOTAL Combination Posture Score	**1**	**1**	**1**	**1**	**2**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	1	2		
Arms	1	2	3	3		
Legs	2	2	2	2		
Posture Repetition (% of working time)	12	24	9	5		
BACK % of Working Time SCORE	1	1	1	1		
ARMS % of Working Time SCORE	1	1	1	1		
LEGS % of Working Time SCORE	1	1	1	1		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 21. Cable Pullers (3/4 inch diameter) OWAS (continued)

Risk Factor	**Work Phase1** **Pull cable**	**Work Phase 2** **Feed cable**	**Work Phase 3** **Change position**	**Work Phase 4** **Adjust cable**	**Work Phase 5** **Tie cables**	**Work Phase 6** **Rest**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	1	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	2	2	3	3	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2	2	2	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	2	2	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	4	16	8	9	5	8

Table 22. Cable Pullers (3/4 inch diameter) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Cable Pull 3/4"

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward? **backwards in this case	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 22. Cable Pullers (3/4 inch diameter) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 22. Cable Pullers (3/4 inch diameter) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	15	9	4	4	11
PERCENTAGE	57.7	81.8	50	50	52.4
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table 23. Equipment Loaders RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Equipment Load In

RULA Component	**Frame # 50490 Lower equipment through hatch**		**Frame # 10110 Roll equipment on low profile cart**		**Frame # 12990 Slide equipment**		**Frame # 22080 Roll equipment on rollers**		**Frame # 22409 Tilt equipment**		**Frame # 18000 Waiting for new load to be delivered**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	mod flex	3	mod flex	3	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		1		1		1		0
Upper Arm Abducted (+1)		0		0		0		1		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	ext	1	neut	2	flx	2	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	mod abd	1	mod abd	1	mod abd	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	mod med	1	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	ext	2	flx	2	ext	2	neut	1
Wrist Deviation	neut	0	neut	0	neut	0	neut	0	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range **Or** (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		3		3		3		0

Table 23. Equipment Loaders RULA (continued)

RULA Component	Frame # 50490 Lower equipment through hatch		Frame # 10110 Roll equipment on low profile cart		Frame # 12990 Slide equipment		Frame # 22080 Roll equipment on rollers		Frame # 22409 Tilt equipment		Frame # 18000 Waiting for new load to be delivered	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		1		2		1		2		2		1
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	sl flx	2	sl flx	2	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		1		1		0
Trunk Side Bend (+1)		0		0		0		1		1		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		3		3		3		0
Total RULA Score	3		4		6		7		7		1	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 24. Equipment Loaders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Equipment Load In

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 24. Equipment Loaders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1495(sec)/ 2910 (sec) = 51	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 108/ 48 min = 2.2	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 24. Equipment Loaders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral (*estimated, based on RULAs performed)	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.0**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 24. Equipment Loaders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
6.0 X	**2.0 X**	**0.5 X**	**1.0 X**	**1.0 X**	**0.75**		**4.5**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 25. Equipment Loaders UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Equipment Load In

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors_____	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?		Y
3.4 Can the tool be used without deviating the wrist from side to side?		Y
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	n/a	n/a
4.2 Can the height of the work surface be adjusted?	n/a	n/a
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	**8 (50%)**	**8 (50%)**

Table 26. Equipment Loaders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 min.)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Equipment Load In

Risk Factor	**Work Phase1** **Lower equipment through hatch**	**Work Phase 2** **Roll equip-ment on low profile cart**	**Work Phase 3** **Slide equip-ment**	**Work Phase 4** **Roll equipment on rollers**	**Work Phase 5** **Tilt equip-ment**	**Work Phase 6** **Waiting for new load to be de-livered**
TOTAL Combination Posture Score	**1**	**3**	**3**	**3**	**2**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	1	2	2			
Arms	1	1	1			
Legs	2	7	6			
Posture Repetition (% of working time)	58	18	11			
BACK % of Working Time SCORE	1	1	1	1		
ARMS % of Working Time SCORE	1	1	1	1		
LEGS % of Working Time SCORE	1	1	1	1		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 26. Equipment Loaders OWAS (continued)

Risk Factor	**Work Phase1** **Lower equipment through hatch**	**Work Phase 2** **Roll equip-ment on low profile cart**	**Work Phase 3** **Slide equip-ment**	**Work Phase 4** **Roll equipment on rollers**	**Work Phase 5** **Tilt equip-ment**	**Work Phase 6** **Waiting for new load to be de-livered**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	2	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	7	7	7	6	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	2	3	3	3	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	12	4	7	7	11	46

Table 27. Equipment Loaders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Equipment Load In

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 27. Equipment Loaders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	N	N			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 27. Equipment Loaders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	7	3	3	12
PERCENTAGE	50	63.6	37.5	37.5	57.1
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table 28. Shipboard Rigger (Equipment Load-In) 3D Static Strength Prediction Program
3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	**BIW**	**Shipboard**	**Equipment load in**
Work Elements: **Shipboard Rigger Tilting Equipment Frame Components**		**Disc Compression (lbs) @ L5/S1** **(Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)**	
Shipboard Rigger tilts equipment: **approximate hand loads of 100 pounds** 		**789 pounds**	

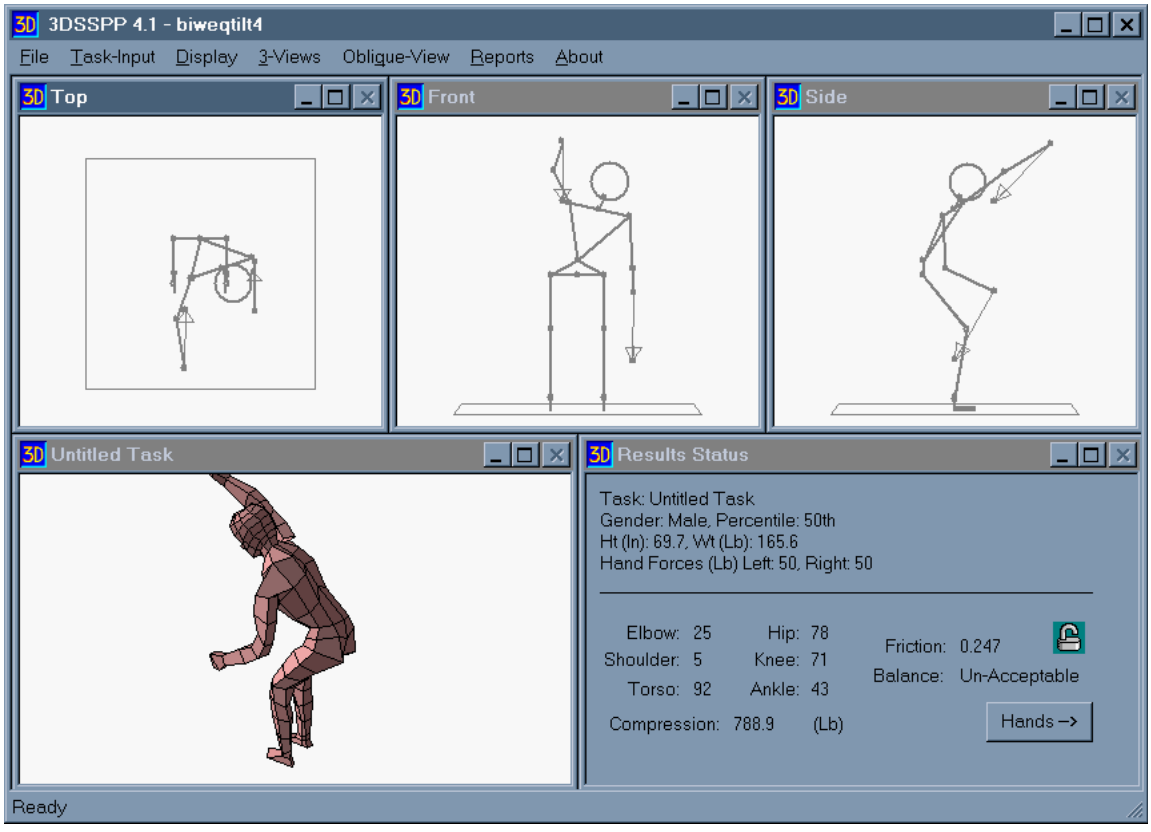


Table 29. Insulation Cutters RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
4/17/99	*BIW*	*Shipboard*	*Insulation Cutters*

RULA: Posture Sampling Results

RULA Component	**Frame # 150000 Measure/ mark**		**Frame # 170220 Change tool**		**Frame # 170490 Cut**		**Frame # 130920 Pass to installer**		**Frame # 128880 Move insulation**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	neut	1	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		0		0		1		0		0
Upper Arm Abducted (+1)		0		0		1		0		1
Arm supported, leaning (-1)		-1		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	mod abd	1	neut	0	mod abd	1
Shoulder Lateral/ Medial	neut	0	neut	0	lat	1	neut	0	lat	1
Wrist Extension/ Flexion	neut	1	neut	1	flx	2	neut	1	neut	1
Wrist Deviation	neut	0	neut	0	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		0		1		0		0

Table 29. Insulation Cutters RULA (continued)

RULA Component	**Frame # 150000 Measure/ mark**		**Frame # 170220 Change tool**		**Frame # 170490 Cut**		**Frame # 130920 Pass to installer**		**Frame # 128880 Move insulation**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	sl flx	2	neut	1	mod flx	3	neut	1	neut	1
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1
Total RULA Score	**3**		**2**		**5**		**2**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 30. Insulation Cutters Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Insulation cutter

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**1.0**

Table 30. Insulation Cutters Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 920(sec)/ 2255 (sec) = 41	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**1.5**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 89/38 = 2.4	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 30. Insulation Cutters Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 30 . Insulation Cutters Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
1.0 X	**1.5 X**	**0.5 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**1.1**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 31. Insulation Cutters UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Insulation Cutter

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors_____	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?		Y
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**14 (64%)**	**8 (36%)**

Table 32. Insulation Cutters OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/99	BIW	Shipboard	Insulation cutter

Risk Factor	**Work Phase1** **Measure/ mark**	**Work Phase 2** **Change tool**	**Work Phase 3** **Cut**	**Work Phase 4** **Pass to installer**	**Work Phase 5** **Move insulation**
TOTAL Combination Posture Score	**1**	**1**	**2**	**1**	**1**
Common Posture Combinations (collapsed across work phases)					
Back	1	2			
Arms	1	2			
Legs	2	2			
Posture Repetition (% of working time)	26	14			
BACK % of Working Time SCORE	1	1			
ARMS % of Working Time SCORE	1	1			
LEGS % of Working Time SCORE	1	1			

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 32. Insulation Cutters OWAS (continued)

Risk Factor	**Work Phase1** **Measure/ mark**	**Work Phase 2** **Change tool**	**Work Phase 3** **Cut**	**Work Phase 4** **Pass to installer**	**Work Phase 5** **Move insulation**
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	2	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	2	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2	2	2
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	20	3	14	1	2

Table 33. Insulation Cutters PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Insulation cutter

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	N				N
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 33. Insulation Cutters PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 33. Insulation Cutters PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	6	5	2	2	4
PERCENTAGE	23.1	45.5	25	25	19
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table 34. Insulation Installers RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	***Facility***	***Area/Shop***	***Task***
4/17/99	*BIW*	*Shipboard*	*Insulation Installers*

RULA: Posture Sampling Results

RULA Component	**Frame # 169050 Wait for cutter, rest**		**Frame # 131100 Place insulation overhead**		**Frame # 152580 Measure, relay info to cutter**		**Frame # 137820 Repo-sition body, ladder**		**Frame # 156840 Trim insulation, cut tie holes**		**Frame # 157680 Install, hammer ties**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	neut	1	hyp flex	4	hyp flex	4	sl flex	2	hyp flex	4	hyp flex	4
Shoulder is Raised (+1)		0		1		1		0		1		1
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	ext	1	ext	1	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	add	1	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	mod med	1	mod med	1	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	ext	2	neut	1	neut	1	ext	2	ext	2
Wrist Deviation	neut	0	ulnar	1	neut	0	neut	0	ulnar	1	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		1		1		1		1		1

Table 34. Insulation Installers RULA (continued)

RULA Component	**Frame # 169050 Wait for cutter, rest**		**Frame # 131100 Place insulation overhead**		**Frame # 152580 Measure, relay info to cutter**		**Frame # 137820 Repo-sition body, ladder**		**Frame # 156840 Trim insulation, cut tie holes**		**Frame # 157680 Install, hammer ties**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	neut	1	ext	4	ext	4	sl flx	2	ext	4	ext	4
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		1
Total RULA Score	**2**		**6**		**5**		**3**		**5**		**5**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 35. Insulation Installers Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Insulation Installers

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 35. Insulation Installers Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1466(sec)/ 2255 (sec) = 65	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 76/38 = 2**, but rather static so set multiplier to 1.0**	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 35. Insulation Installers Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation (*estimated, based on RULAs performed)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**2.0**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 35. Insulation Installers Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**2.0 X**	**1.0 X**	**2.0 X**	**1.0 X**	**1.0**	**=**	**12**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 36. Insulation Installers UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Insulation Installer

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors_____	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**15 (68%)**	**7 (32%)**

Table 37. Insulation Installers OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/99	BIW	Shipboard	Insulation Installing

Risk Factor	**Work Phase1** **Wait for cutter, rest**	**Work Phase 2** **Place insulation overhead**	**Work Phase 3** **Measure, relay info to cutter**	**Work Phase 4** **Repo-sition body, ladder**	**Work Phase 5** **Trim insulation and cut tie holes**	**Work Phase 6** **Install, hammer ties**
TOTAL Combination Posture Score	**1**	**2**	**2**	**1**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	2				
Arms	1	3				
Legs	2	2				
Posture Repetition (% of working time)	39	55				
BACK % of Working Time SCORE	1	2				
ARMS % of Working Time SCORE	1	2				
LEGS % of Working Time SCORE	1	1				

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 37. Insulation Installers OWAS (continued)

Risk Factor	**Work Phase1** **Wait for cutter, rest**	**Work Phase 2** **Place insulation overhead**	**Work Phase 3** **Measure, relay info to cutter**	**Work Phase 4** **Repo-sition body, ladder**	**Work Phase 5** **Trim insulation and cut tie holes**	**Work Phase 6** **Install, hammer ties**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	2	2	1	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	3	3	1	3	3
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2	2	2	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	32	14	20	7	9	12

Table 38. Insulation Installers PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Insulation Installers

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 38. Insulation Installers PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	N	N			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 38. Insulation Installers PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	5	5	5	12
PERCENTAGE	50	45.5	62.5	62.5	57.1
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table 39. Panel Line Wire Welders RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99	BIW	Shipboard	Panel Line Wire Welding

RULA: Posture Sampling Results

RULA Component	**Frame # 72270 Inspect**		**Frame # 74010 Grinding crouched/ kneeling**		**Frame # 85290 Change tool**		**Frame # 87120 Wire weld kneeling**		**Frame # 96240 Re-arrange equip-ment**		**Frame # 92220 Change position**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	mod flex	3	mod flex	3	neut	1	mod flex	3	sl flex	2	sl flex	2
Shoulder is Raised (+1)		0		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		-1		0		0		-1		-1		0
Elbow Extension/ Flexion	neut	2	ext	1	ext	1	neut	2	ext	1	neut	2
Shoulder Abduction/ Adduction	neut	0	add	1	neut	0	add	1	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	mod med	1	neut	0	mod med	1	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	ext	2	neut	1	ext	2	neut	1	neut	1
Wrist Deviation	neut	0	ulnar	1	neut	0	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		1		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		0		1		1		2		1		1

Table 39. Panel Line Wire Welders RULA (continued)

RULA Component	**Frame # 72270 Inspect**		**Frame # 74010 Grinding crouched/ kneeling**		**Frame # 85290 Change tool**		**Frame # 87120 Wire weld kneeling**		**Frame # 96240 Re-arrange equip-ment**		**Frame # 92220 Change position**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	extr flx	3	extr flx	3	sl flx	2	ext	4	ext	4	ext	4
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	mod flx	3	neut	1	extr flx	4	mod flx	3	mod flx	3
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		2		1		1
Total RULA Score	**3**		**5**		**2**		**7**		**3**		**3**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 40. Panel Line Welders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line	Panel Line Wire Welding

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 40. Panel Line Welders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 720(sec)/ 1321 (sec) = 54	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = nearly static exertion, therefore **multiplier = 3**	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**3.0**

Table 40. Panel Line Welders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 40. Panel Line Welders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.0**	**=**	**27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 41. Panel Line Welders UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Panel Line Wire Welding

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors_____	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (welding)
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**12 (57%)**	**9 (43%)**

Table 42. Panel line welders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Shipboard	Panel Line Wire Welding

Risk Factor	**Work Phase1** **Inspect**	**Work Phase 2** **Grinding crouched /kneeling**	**Work Phase 3** **Change tool**	**Work Phase 4** **Wire weld kneeling**	**Work Phase 5** **Re-arrange equip-ment**	**Work Phase 6** **Change position**
TOTAL Combination Posture Score	**2**	**1**	**1**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	2	1		
Arms	2	1	1	1		
Legs	4	1	6	4		
Posture Repetition (% of working time)	48	14	20	9		
BACK % of Working Time SCORE	1	1	1	1		
ARMS % of Working Time SCORE	2	1	1	1		
LEGS % of Working Time SCORE	2	1	1	1		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 42. Panel line welders OWAS (continued)

Risk Factor	Work Phase1 **Inspect**	Work Phase 2 **Grinding crouched /kneeling**	Work Phase 3 **Change tool**	Work Phase 4 **Wire weld kneeling**	Work Phase 5 **Re-arrange equip-ment**	Work Phase 6 **Change position**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	1	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	6	7	6	6	7
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	2	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	48	7	7	8	12	9

Table 43. Panel Line Welders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
4/17/00	BIW	Panel line	Panel Line Wire Welding

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 43. Panel Line Welders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 43. Panel Line Welders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	6	3	3	10
PERCENTAGE	50	54.5	37.5	37.5	47.6
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table 44. Tank Grinders 1 RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99	BIW	Shipboard	Tank Grinding 1

RULA: Posture Sampling Results

RULA Component	**Frame # 30210 Grinding; disc (5 in)**		**Frame # 44640 Tool Change**		**Frame # 40470 Pad Change**		**Frame # 19710 Grinding; disc (3in)**		**Frame # 22080 Wire Brush**		**Frame # 60450 Needle Gun**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	mod flex	3	neut	1	neut	1	sl flex	2	sl flex	2	sl flex	2
Shoulder is Raised (+1)		1		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	neut	2	flx	2	neut	2	flx	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	add	1	add	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	mod med	1	mod med	1	neut	0
Wrist Extension/ Flexion	flx	2	neut	1	neut	1	ext	2	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0	neut	0	ulnar	1	rad	1	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range **Or** (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2		2

Table 44. Tank Grinders 1 RULA (continued)

RULA Component	Frame # 30210 Grinding; disc (5 in)		Frame # 44640 Tool Change		Frame # 40470 Pad Change		Frame # 19710 Grinding; disc (3in)		Frame # 22080 Wire Brush		Frame # 60450 Needle Gun	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion		1		1		1		4		4		1
Neck Twist (+1)		0		0		0		1		0		0
Neck Side-Bent (+1)		0		0		0		1		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1	sl flx	2	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		1		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		2		2
Total RULA Score	6		3		3		7		7		5	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 45. Tank Grinders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99	BIW	Shipboard	Tank Grinding 1

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	**% MS** *(percentage of maximal strength)*	**Borg Scale** *(Compare to Borg Cr-10 Scale)*	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**6.0**

Table 45. Tank Grinders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 2726 (sec)/ 2988 (sec) = 91	**Rating Criterion**	**Rating**	**Multiplier**
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**3.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = nearly static exertion, therefore **multiplier = 3**	**Rating Criterion**	**Rating**	**Multiplier**
	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**3.0**

Table 45. Tank Grinders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension** *(Stetson et al, 1991)*	**Wrist Flexion** *(Stetson et al, 1991)*	**Ulnar Deviation** *(Stetson et al, 1991)*	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** *(observed pace is divided by MTM's predicted pace and expressed as %)*	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 45. Tank Grinders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate @ 2-4 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	**=**	**SI SCORE**
6.0 X	**3.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**0.75**		**60.8**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 46. Shipboard Tank Grinders UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99	BIW	Shipboard	Tank Grinding 1

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors_____	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (grinder)
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**14 (64%)**	**8 (36%)**

Table 47. Tank Grinders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99	BIW	Shipboard	Tank Grinding 1

Risk Factor	**Work Phase1** **Grinding disc (5 in)**	**Work Phase 2** **Tool Change**	**Work Phase 3** **Pad Change**	**Work Phase 4** **Grinding disc (3in)**	**Work Phase 5** **Wire Brush**	**Work Phase 6** **Needle Gun**
TOTAL Combination Posture Score	**2**	**1**	**1**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	1	1	2	1		
Arms	2	1	1	1		
Legs	4	1	6	4		
Posture Repetition (% of working time)	48	14	20	9		
BACK % of Working Time SCORE	1	1	1	1		
ARMS % of Working Time SCORE	2	1	1	1		
LEGS % of Working Time SCORE	2	1	1	1		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 47. Tank Grinders OWAS (continued)

Risk Factor	**Work Phase1** **Grinding disc (5 in)**	**Work Phase 2** **Tool Change**	**Work Phase 3** **Pad Change**	**Work Phase 4** **Grinding disc (3in)**	**Work Phase 5** **Wire Brush**	**Work Phase 6** **Needle Gun**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	1	1	6	6	4
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	1	2	2	2
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	48	7	7	8	12	9

Table 48. Tank Grinders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
7/26/99	BIW	Shipboard	Tank Grinding 1

Section I: Musculoskeletal Risk Factors
Methods of Application:
1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 48. Tank Grinders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 48. Tank Grinders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	14	9	5	5	11
PERCENTAGE	53.8	81.8	62.5	62.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying) **Answer below questions, use to modify interpretation of musculoskeletal scores**					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	6				
PERCENTAGE	60.0				